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**Apparatus and Method For Automatic Network Connection
Provisioning**

Inventor:

Jim Mao

Prepared by:

Blakely, Sokoloff, Taylor & Zafman LLP
12400 Wilshire Boulevard, Seventh Floor
Los Angeles, California 90025-1026
(408) 720-8598

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Apparatus and Method For Automatic Network Connection Provisioning

FIELD OF THE INVENTION

The field of invention relates generally to networking management techniques; and more specifically, to a method an apparatus that automatically provisions a connection within a network.

BACKGROUND

Figure 1 shows an exemplary network 100. A network 100 is implemented with a plurality of machines (referred to as a switches, routers, or nodes) interconnected by a plurality of links. For example, as seen in the exemplary network 100 of Figure 1, nodes 101 through 109 are interconnected by links 111 through 125. A connection is a path through a network, such as path 126 seen in Figure 1. A connection based network is a network that can send data from a source to a destination via a connection.

If a user of the network 100 desires to send information from a source A to a destination B, the connection 126 is first established through the network 100. Many different types of networking technologies employ connections in order to transport data. Connection based networking technologies include Asynchronous Transfer Mode (ATM), Multi-Protocol Label Switching (MPLS), Frame Relay, Synchronous Optical NETwork (SONET), and Wavelength Division Multiplexing (WDM) among others.

In many common circumstances, a user desires to establish a networking service relationship with a networking service provider (i.e., an entity or individual that offers the use of a network to a user). For example, a corporate user having an office at source A (e.g., New York City) may desire to send/receive information to/from another office at destination B (e.g., Chicago) over the course of business for the next calendar year.

A connection based service having defined characteristics as to the transportation of information between the source A and the destination B may be established by the service provider for the corporate user. For example, the service provider may guarantee that the network 100 will be able to accept an offered load of X Mb/s (or less) from the user at source A that will be delivered at the destination B with no more than Y seconds of end-to-end delay from the source A to the destination B.

The characteristics of the connection (e.g., the source/destination pair A/B, the path 126 through the network, the bandwidth allocation of X Mb/s at the source and the Quality of Service (QoS) of no more than Y seconds of delay across the network) are effectively stored by the service provider's network. When the corporate user attempts to send information from source A to destination B, the network 100 detects the attempt and establishes the connection according to its characteristics.

Connection provisioning is the configuring of a new connection into the repertoire of connections supported by a network. Connection provisioning

involves determining: 1) the path for a connection; 2) the amount of the network's resources (e.g., bandwidth) used to support the connection; and 3) the storing of connection characteristics (e.g., a next hop node, switching or routing capacity resources to devote to the connection, etc.) into the nodes of the network so that the nodes can establish the connection when it is requested by the user.

A problem with connection provisioning is that it is manually intensive. That is, connections are currently provisioned into a network by manually entering next hop information into each node within the network that is used to support the connection. As a result, significant time is consumed from the moment a user is able to present characteristics of a desired connection (e.g., a source, a destination, a bandwidth, an in transit delay, etc.) to a service provider to the moment that the connection is configured into the network 100 so that it can establish such a connection afterward.

In related instances, significant time is also consumed trying to "bring-up" a network (e.g., from a nodal or other network system failure) because the connections have to be manually re-provisioned. In still other related instances, network connection provisions cannot be quickly adjusted to take advantage of changing networking conditions because the manual provisioning process is too cumbersome.

SUMMARY OF INVENTION

A method comprising selecting a connection source and a connection destination from a graphical user interface that displays a topology of a network. Then, executing a routing algorithm to determine a path through the network. Then, provisioning the connection within the network that corresponds to the path.

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Figure 1 shows a network topology;

Figure 3 shows a distributed, automatic connection provisioning approach; and

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DETAILED DESCRIPTION

A method is described that involves selecting a connection source and a connection destination from a graphical user interface that displays a topology of a network. Then, executing a routing algorithm to determine a path through the network. Then, provisioning the connection within the network that corresponds to the path.

A solution to the cumbersome manual connection provisioning process described in the background is an automatic connection provisioning process. That is, based upon a user's desired connection characteristics (e.g., source/destination pair, bandwidth and quality of service), the network itself is able to provision the connection into the network. In the discussion that follows, a centralized automatic network provisioning method and apparatus embodiment are first described followed by a distributed automatic network provisioning method and apparatus.

Figure 2 shows a network 200 having centralized automatic network provisioning capability. As developed in the description that follows, a routing algorithm 250 within a network control system 230 develops the appropriate path through the network 200 for a desired connection. The connection is then provisioned into the network 200 by the network control system 230.

Referring to Figure 2, individuals responsible for maintaining the operation of a network 200 (also referred to as network control station operators) interact with a network through a network control station 270. A network

control station 270 typically includes two components: a network management system 220 and a network control system 230. The network management system 220 acts as an interface between a network control station operator and the network control system 230.

A network control system 230 typically includes one or more software programs that collectively possess an understanding of the network's topology, resources, and the allocation of these resources. The network management system 220 presents the network control station operator with the understanding possessed by the network control system 230 (e.g., via a graphical user interface (GUI) 227).

A network's topology is a network's specific pattern of nodes and the links that exist between them. A network's resources are the switching or routing capacities of its nodes and the transmission capacities of its links. A network's resource allocation is a description of how its resources are organized (such as a listing of the connections provisioned into the network). Thus, for example, through the network management system 220 a network control station operator can view: 1) the location and capacity of each node (e.g., nodes 201 through 209); 2) the location and capacity of each link (e.g., links 211 through 225); and 3) the connections provisioned into the network.

The network control system 230 is shown coupled to the network 200. The network control system 230 sends control messages into the network 200 to control the resources of the network 200 and also receives control messages from

the network 200 to monitor the resources of the network 200. For example, in various embodiments, the network control system 230 can forward to each access node (though one or more control messages) the amount of routing capacity it should devote to each connection it interfaces to a user with (e.g., either at the source of a connection or at the destination of a connection). An access node is a point of entry or exit from a network (such as nodes 201 and 207 as seen in Figure 2).

If a new connection is to be provisioned into the network (e.g., that follows path 226 seen in Figure 2), look up tables within the nodes used to carry the connection (e.g., nodes 201, 204, 205, 206, 207) are typically updated so that packets, cells, time slots (or perhaps other data structures) may be properly passed from a receiving node to a next node according to the connection path 226. Other information associated with the connection may also be stored into the nodes used to carry the connection such as the amount of switching resources a node is to devote to the connection or the priority of the connection (so that its information may be routed sooner rather than later through the node).

Thus the network control system 230, in order to provision the new connection within the network 200, may send to one or more control messages into the network 200 that effectively command the network nodes to update their look up tables (or other databases) accordingly. The network control system 230 also collects control messages sent from the network 200 that indicate various network events (e.g., a link shutdown or a node shutdown) or traffic statistics.

network topology 200 is shown in Figure 2) may be visually presented to the network control station operator as part of the functionality of the network management system 230. The graphical interface 227 may be configured to show the topology of the network (i.e., the nodes of the network as well as the links of that interconnect them). The network control station operator, by pointing and clicking at a source and a destination can automatically generate the source/destination pair characteristics of the connection.

Furthermore, the graphical user interface 227 may prompt the network administrator (e.g., via a pop up window or form, etc.) for additional connection characteristics such as: 1) the networking technology employed at the source and/or destination access nodes (e.g., Asynchronous Transfer Mode (ATM), Multi-Protocol Label Switching (MPLS), Frame Relay (FR), Time Division Multiplexing (TDM), Synchronous Optical Network (SONET), and Wavelength Division Multiplexing (WDM) among others, etc.); and 2) the bandwidth allocation at the source access node and/or the destination access nodes. The network characteristics may also include various QoS parameters such as: 1) the end to end delay across the connection; 2) the jitter in the connection; 3) the error rate; etc.

Upon the selection of the source/destination points (and perhaps the entry of additional network characteristics) through the graphical user interface 227, a set of connection characteristics that describe the connection are generated and sent as a request 260 to the network control system 230. In the centralized,

automatic networking provisioning approach of Figure 2, the network control system 230 includes a routing algorithm 250 that determines a best path through the network 200.

A routing algorithm (e.g., Routing Information Protocol (RIP), Open Shortest Path First (OSPF), derivatives of these, etc.) is an algorithm that determines an end to end best path through a network 200. In an embodiment, the routing algorithm 250 has bandwidth and/or QoS based routing extensions. A routing algorithm having bandwidth and/or QoS based routing extensions not only keeps track of topology information but also keeps track of bandwidth and/or QoS related information.

As such, the best routing path through the network is based upon the resources of the network (in the form of nodal switching/routing capacity and link speed) rather than simply counting the fewest number of nodal hops (as is the case with traditional routing algorithms). For example, in a source routing approach (such as OSPF) having bandwidth and QoS extensions, weights may be given to each link and node within the network 200 that reflect the available resources at the node or link.

The weight of a node or link may increase as the resources become constrained and decrease as resources become available. As such, the best path through the network corresponds to the combination of nodes and links having the lowest combined weight from the source access node to the destination access node. Note that the routing algorithm may have sufficient granularity to

understand the resources available for each networking technology (e.g., ATM, MPLS, FR, TDM etc.). For example, a separate weight may be tracked for each networking technology employed.

Based upon the path determined by the routing algorithm, the network control system 230 can also determine the effect that the proposed connection may have on the performance of other connections (e.g., in the form of additional delay associated with the nodes used to transport the proposed connection).

If the network can support the proposed connection (e.g., by comparing the bandwidth and/or QoS requirements of the proposed connection defined by the request 260 against those associated with the best path determined by the routing algorithm) and if implementing the proposed connection does drop the performance of other connections beneath their minimum allowable performance level (e.g., with respect to their individual bandwidth and QoS requirements), the proposed connection is provisioned into the network.

That is, the request 260 is answered affirmatively. The network control system 230 then sends appropriate control messages into the network 200 that effectively provision the connection. If the network cannot support the proposed connection or its implementation will unacceptably affect the other connections supported by the network, the request 260 is answered negatively.

In an alternate embodiment, the routing algorithm 250 determines the two best paths through the network 200. The pair of best paths are then provisioned into the network 200 where one of the paths is a redundant path. As an example,

either 1+1 redundancy or 1:1 redundancy may be implemented. In the case of 1+1 redundancy both paths are simultaneously used in parallel. That is, the information in the connection is simultaneously sent twice along two different paths in the network 200. In the case of 1:1 redundancy, the redundant path is used only if the other path is not operable (e.g., because of a link failure along the path route).

Figure 3 shows an alternate embodiment in which the routing algorithm is distributed over each of the nodes 301 through 310 in the network 300. That is, whereas the centralized approach of Figure 2 isolates within the network control system 230 the determination of the best path through the network 200; the distributed approach of Figure 3 uses routing algorithms 350a through 350i installed on each node 301 through 309 in the network.

The characteristics of the user's proposed connection are passed from the network management system 320 to the network control system 330 (in the form of a request 360) as discussed above with respect to the approach of Figure 2. In the distributed approach of Figure 3, the request 360 is translated into a request control message 361 that is sent from the network control system 330 into the network 300. The request associated with the request control message 361 is then effectively passed to each node in the network (or at least each node that would be used to carry the connection).

In a distributed routing algorithm approach, the nodes 301 through 309 in the network 300 exchange information that reflect the topology of the network

300. Based on the exchanged topology information, each network node 301 through 309 is able to develop an understanding of the topology of the network 300. Furthermore, the exchanged information may also include bandwidth and/or QoS related information.

As such, a routing algorithm having bandwidth and/or QoS extensions may be executed on each node 301 or 309. Based upon its understanding of the topology and resource constraints of the entire network (as described above with respect to the routing algorithm 250 of Figure 2), each node can determine the best path through the network for a proposed connection and therefore determine which node is the appropriate "next node" for the connection (for those nodes the best path happens to flow through).

Each of the nodes that will be used to carry the proposed connection respond to the request control message 361 with a response control message that indicates whether or not the node has sufficient resources to entertain the connection and if so, the delay or other resource constraints that may impair the performance of other connections already supported by the network .

After collecting the response control messages, the network control system 330 decides whether or not the connection should be provisioned for. If so, the request 360 is answered affirmatively and a control message is sent into the network 300. The look up tables of the affected nodes are updated accordingly. Similar to the approach of Figure 2, redundant connection paths

may also be configured of at least two paths are determined by the distributed routing algorithms 350a through 350j.

Figure 4 shows a methodology that describes the operation of the centralized and distributed automatic provisioning approaches discussed above. A source and destination node are selected 401 (e.g., by pointing and clicking) from a network topology presented to a network control station operator by a graphical user interface.

Then, additional characteristics to be associated with the connection (e.g., bandwidth and/or QoS parameters) are selected or otherwise entered 402 (e.g., via a form or pop up menu). These characteristics are then made available to a routing algorithm having bandwidth and/or QoS routing extensions.

The routing algorithm having bandwidth and/or QoS extensions is then executed 403 to determine the best path through the network from the source to the destination. If the network can entertain the connection it is provisioned 404 into the network, otherwise the network control station operator is informed 405 that the proposed connection cannot be provisioned.

Because the routing algorithms, network management systems and network control systems discussed above may be implemented at least partially with a software, it is to be understood that embodiments of this invention may be used as or to support software programs executed upon some form of processing core (such as the CPU of a computer) or otherwise implemented or realized upon or within a machine readable medium.

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A machine readable medium includes any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computer). For example, a machine readable medium includes read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other form of propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.); etc.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.